OBSERVATIONS

ON

CANADIAN GEOLOGY.

By THOMAS MACFARLANE.

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INTRODUCTION.

As long ago as in 1862, I ventured to express the opinion that the greater part of the rocks of South-eastern Quebec belonged to the schistose group of the primitive Slate Formation, and were of an age prior to that of the Silurian or indeed of any fossiliferous strata.* In 1868, after a careful examination of the upper copper-bearing rocks of Lake Superior, I called attention to the analogy which, in lithological respects, exists between them and the Permian strata as developed in many parts of Germany. Subsequent observations and study have only tended to strengthen the impression which I, at those times, acquired as to the age of these groups of rocks. After adopting these conclusions, I attempted earnestly to bring them into agreement with the views generally entertained regarding the age of the fossiliferous strata developed in the valley of the St. Lawrence. My efforts in this direction did not lead to a satisfactory result, but, on the contrary, tended to create in my mind a feeling of want of confidence in much that had been taught concerning the age of these fossiliferous rocks. Two alternatives thus became presented to me, either to regard my conclusions about the rocks of the Eastern Townships and Lake Superior as erroneous, or to proceed in the course I had begun, and possibly in the end come to reject very many of the views generally held on Canadian geology. I chose the latter course, and followed it not without much hesitation and misgiving, and at last reached conclusions which I have, for a long time, deferred making public. I do not know that even now I would "rush into print" on these matters, were it not for the recent publication by Dr. Hunt of his Address to the American Asso-

* Canadian Naturalist; VII, 171.

ciation for the Advancement of Science. In this I find some reference to formerly expressed views of mine, which, however, will scarcely bear the interpretation which Dr. Hunt attaches to them. I have, therefore, felt constrained to advance, in my own words, my ideas on the subjects discussed in the Address, and at the same time to place upon record my views upon the other important points in our geology above referred to. Another consideration in favour of this course is that these views, if really sound, lead to deductions which possess some significance as regards the economic resources of the Province of Quebec. Even if the most of these observations should be judged to be unfounded or trivial, I indulge the hope that some of them will be found worthy of such an amount of attention as will cause a re-examination of some of the prevailing ideas regarding the geological structure of the country. Although the positions taken appear to my mind to be almost incontrovertible, I am far from wishing to put them forward positively as the only correct ones. I can conceive that other geologists, looking at the matter from a different point of view, may arrive at conclusions very different from mine. I would therefore prefer to have them regarded as suggestions or theorisings which may tend to throw light upon some of our obscure geological problems.

On the geological map of Canada we find indicated by the same colour three groups of rocks, which nevertheless exhibit the widest differences in their petrological, stratigraphical, and palæontological characters. I refer to the Quebec group, the Calciferous sandstone, and the Upper copper-bearing rocks of Lake Superior. They are all regarded as belonging to the Silurian system, to the same subdivision of that system, the Lower Silurian, and even as being members of that subdivision exactly corresponding in geological age. Yet I think it is possible to maintain that no three geological groups are more dissimilar. The true Calciferous sandstone of the valley of the St. Lawrence consists of interstratified beds of sandstone, dolomite, and argillite, having a thickness of thirty feet, a nearly horizontal position, and a few fossils, among which neither graptolites nor trilobites are mentioned. The Quebec group has an exceedingly diversified petrological constitution, being made up of black, green, and gray shales, green and gray sandstones, limestones, dolomites, roofing slates, chloritic, nacreous, and mica schists, quartzites, serpentines, greenstones, and many other rocks. It has a thickness of at least

7000 feet, and a very complicated build, being thrown into numerous anticlinal and synclinal folds. A large part of its rocks are semi-crystalline, and destitute of organic remains, while another and smaller zone contains characteristic Lower Silurian fossils. The Upper copper-bearing district of Lake Superior has nothing in common with either of its supposed equivalents. Grey flagstones and shales, variegated sandstones and indurated marls; conglomerates, porphyries, melaphyres, aphanites, pitchstones, and amygdaloids; trachytes, augitic porphyries, hyperites, and characteristic basalts combine together in different parts of its area to form different groups of rocks, none of which bear the slightest resemblance to either the Calciferous sandstone or the Quebec group. Both of these are exceeded by the Lake Superior rocks as regards their thickness, and as to position, the latter exhibit every degree of inclination from 5° to 90°, although no corrugations of their strata are observable. In palæontological respects the divergence is equally great, for although the Calciferous sandrock possesses a few fossils, and the Quebec group a rich and characteristic fauna, no organic remains whatever have yet been discovered among the upper copper-bearing rocks of Lake Superior.

Those three groups of strata not only possess altogether distinct characters as regards their rocks, structure, thickness, and fossils, but their mutual relations are such as to exclude the idea of their being of contemporaneous origin. Nowhere can any one of them be traced as standing in uninterrupted connection with another, and where they approach nearest to each other, their attitudes indicate that there is little affinity between them. I fail to appreciate the reasons for their ever having been classed together, and would doubtless fail to do these reasons justice were I to attempt to describe them here. Instead of doing so, I shall endeavour to show that the larger part of the rocks of the Quebec group are pre-Silurian, and may with all propriety be entitled Cambrian; that its fossiliferous part alone is Lower Silurian, and may be overlaid by much newer rocks beneath the alluvium of the St. Lawrence valley; that the upper copper-bearing rocks of Lake Superior may be divided into Permian, Triassic, and Eruptive rocks, while the Calciferous sandstone and some of the almost horizontal fossiliferous strata of Quebec, are of an age more recent than that of the Carboniferous period.

The views advanced by Dr. Hunt in the Address above referred

to regarding the structure and age of the Appalachian rock-masses, have also reference to the age of the Quebec group, the crystalline part of which he regards as not only pre-Silurian, but pre Cambrian, and in fact Huronian. It would occupy too much space to follow Dr. Hunt in his able exposition of the various theories put forward as regards the structure and age of the Green Monntain and White Mountain rocks. It will be sufficient here to state, as briefly as possible, the theoretical conclusions which he regards as most tenable. In the first place, the rocks of the Laurentides, the Green Mountains, and the White Mountains, are regarded as distinct series with different lithological and mineral characters, and it is maintained that these three series may be traced into Canada and the neighbouring States, and recognized as occurring in other countries. These rocks are exclusively crystalline, but nevertheless regarded as of sedimentary origin. The Green Mountain rocks are separated from the highly inclined fossiliferous strata which border them on the west, the so-called Taconic rocks, which with some of the more horizontal Champlain rocks, are regarded as upper Cambrian. Rogers' view of the mutual relations of these rocks is defended, in opposition to that of Emmons, who maintained that the Champlain division overlies unconformably the so-called Taconic formation, and that consequently the latter must be of earlier age. While the Green Mountain rocks are regarded as of Huronian age, those of the White Mountains are considered to be distinct from and newer than both Laurentian and Huronian, and are provisionally called the Terranovan series. Dr Hunt concludes: "Although I have, in common with most other Amer-"ican geologists, maintained that the crystalline rocks of the "Green Mountain and White Mountain series are altered palæo-"zoic sediments, I find, on a careful examination of the evidence, "no satisfactory proof of such an age and origin, but an array of "facts which appear to me incompatible with the hitherto re-"ceived view, and lead me to conclude that the whole of our "crystalline schists of eastern North America are not only pre-"Silurian but pre-Cambrian in age." We are thus led to conclude that Dr. Hunt regards the following as the true classification and order of succession among these early geological formations:—1. The Laurentian or Adirondack series; 2. The Huronian or Green Mountain series; 3. The Terranovan or White Mountain series; 4. The Cambrian series, comprising the Lower Cambrian (the strata holding Paradoxides in Newfoundland,

New Brunswick, and Eastern Massachusetts), and the Upper Cambrian (the lower half of the Champlain division from the base of the Potsdam to the summit of the Levis formation, including of course the Taconic rocks); 5. The Silurian series.

In considering Dr. Hunt's views and advancing my own, it will be well to treat of the various subjects under the heads of the different systems to which they have reference, and in the order which I conceive them to have geologically.

I.—THE LAURENTIAN SYSTEM.

Dr. Hunt endeavours to draw a distinction, lithologically and geognostically, between the Adirondack and the White Mountain rocks, and proposes to regard the latter as a distinct series, the Terranovan. The comparative scarcity of mica in the gneiss, the rarity of characteristic mica schists, and the complete absence of argillites, are given as distinguishing features of the Laurentian, while the predominance of micaceous gneiss and mica schists containing garnet and other minerals, is regarded as characteristic of the White Mountain series. No doubt the two series exhibit such general differences, but it may well be doubted whether they are sufficiently prominent to justify the erection of a new geological system.

In the gneissic rocks of the Saxon Erzgebirge, we have the exact counterpart of the White Mountain series, while in many parts of Scandinavia, large areas of Laurentian gneiss are developed. Yet, Naumann, who was thoroughly acquainted with both countries, perhaps perceiving the uselessness of minute distinctions among these ancient rocks, classes both series under Primitive Gneiss. To the same formation he refers the gneissoid rocks of New England, deriving apparently most of his information on the subject from Hitchcock's Geology of Massachusetts.

No doubt the same view would have found favour with the majority of geologists to the present day, had not the idea of the sedimentary origin of these rocks, and the consequent theories of metamorphism been promulgated, to which I believe are to be attributed all the confusion and diversity of opinion which prevail as to the classification and origin of these ancient formations. Instead of treating these like other geological series, and regarding the phenomena which their rocks now present to us, as original and characteristic, a certain school of geologists has maintained

these crystalline rocks to be altered or metamorphosed sediments, to have resulted from a "molecular re-arrangement" of the constituents of pre-existing detrital rocks, or to have been formed from them in some mysterious chemical manner, of which it is very difficult indeed to form a distinct idea. The parallelism which may be observed in the arrangement of their constituent minerals has been assumed as indisputable evidence of their sedimentary deposition, altogether regardless of the fact that very many undoubted igneous rocks exhibit entirely analogous phenomena. Carried away by these theories of metamorphism, the school of geologists already mentioned have been continually striving to discover the unaltered equivalents of these crystalline rocks. Owing to the assumed obliteration of the fossils in the latter, the search for the "unaltered equivalents," has been pursued without chart or compass, and the result is a mass of contradictory theorising, in which the earnest student feels himself entirely lost, and the unscientific public entertain not the slightest confidence. Thus it is that the rocks of the White Mountains have been by turns regarded as metamorphosed Cambrian, Silurian, Devonian, and even Carboniferous strata, and now we have another theory advanced, according to which they form the Terranovan, an entirely new series, the "unaltered equivalent" of which does not now appear to exist, or be visible anywhere upon the surface of the globe. The same view is entertained as to the Laurentian series. Even it, the oldest known formation, is "composed of crystalline stratified deposits, presumed to be of sedimentary origin,"* but not the slightest hint is obtainable as to the nature of the sedimentary rocks from which they resulted. And this is not all. "Before these," says Dr. Hunt, "the imagination conceives yet earlier rocks, until we reach the surface "of unstratified material which the globe may be supposed to "have presented before water had begun its work." What this unstratified material consists of, and whether it is anywhere visible on the surface of the earth, are points on which Dr. Hunt does not enlighten us.

To this "bottomless hypothesis," as it has been called, the simple theory may be opposed that the greater portion of the Laurentian rocks, including the gneissic strata of the White Mountains, constitute that part of the crust of our planet which

* Dr. Hunt's Address, p. 38.

first underwent solidification. The prevailing schistose structure of these rocks may be accounted for by supposing that, at the time of the crystallisation, their material was, from some cause or other, kept in motion. Nothing is more conclusively established than that there exists, at the present day, in the atmosphere and ocean, a series of currents caused by the diurnal motion of the earth. May not similar currents have been in operation in the fluid igneous material during the first solidification of the earth's crust? Is it not possible that, after this solidification had commenced, the outer shell may have moved quicker than the fluid interior, from west to east, and that the gradual accumulation of crystallised rock on the interior of the crust may have taken place under circumstances similar to those so well described by Naumann in referring to the parallel structure of certain igneous rocks?* There are not wanting instances of the formation of slaty structure in artificially formed slags from a similar cause, and nothing is more common than to observe in slags from iron furnaces a distinct streaked or banded appearance, evidently caused by the different rate of motion in the interior and outside parts of the stream flowing from the furnace. This is simply another instance of the production of a stratified appearance similar to those described by Tyndall in his work "On the glaciers of the Alps." He there shows that the banded appearance of glacier ice, the lamination of wax subjected to pressure, and the fibrous texture of rolled iron, are caused by the motion under pressure of the atoms constituting those substances. From these facts, and considering that the existence of internal currents at that period is highly probable, it would appear not unreasonable to expect that some of the rocks solidified on the surface of the fluid globe, would have a schistose structure. It is impossible to suppose that the particles of the fluid material, beneath the solidifying crust, would always preserve the same relative position to the latter, in spite of the daily revolution of the globe. The liquid rock beneath the crust must have moved in one direction or other almost as freely as the water of a frozen river under the ice which covers it. The schistose structure resulting from this solidification under motion must however have resembled more the lamination of certain igneous rocks than the stratification of sedimentary strata, and this is exactly what we

* Canadian Naturalist; VIII, 375.

observe in the structure of gneissoid rocks. It is easy to conceive how the constituent minerals of gneiss, as they gradually crystallized out, may have arranged themselves with their longer axes parallel to the direction of the igneous currents. The idea that gneiss may have been formed in the manner here indicated was first put forward by me in 1864,* but was not then entirely new. In 1845 it had been stated that the gneiss of the Saxon Erzgebirge "perhaps differs only from granite because it solidified "under the influence of certain pressures or tensions." †

It is impossible to adduce stronger arguments against the "bottomless hypothesis" than those advanced by Naumann, of which I have elsewhere given a translation,‡ and, even more recently, in language quoted by Dr. Hunt himself we have Naumann again entering his protest against the metamorphic origin of gneissic rocks. "It appears to me, moreover," he says, "that "geologists commit an analogous error when they regard gneisses, "amphibolites, etc., as being, all of them, the results of meta-"morphic epigenesis and not original rocks."§

As regards the differing geological relations of the Laurentian series and the White Mountain rocks they can readily be accounted for by supposing that the former remained exposed above the surface of the primitive ocean, for a long time, during which certain parts of the gneissoid rocks of the White Mountains and Green Mountains were being acted upon energetically by the waters of that ocean, and accumulations of slate and other rocks were being deposited on them. When at last the gneissoid rocks were elevated and corrugated by the protrusion of the granitic nucleus of the White Mountains, or by the action of some force having its seat farther eastward, they were of course accompanied by the rocks which covered them up, which rocks are found to have been affected by the action of the same forces. I therefore conceive that there is no necessity for dividing up the old Primitive Gneiss formation, and no good reason for regarding the White Mountain rocks as distinct from Sir W. E. Logan's Laurentian system.

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* Canadian Naturalist; VIII, p. 463.

† Canadian Naturalist; VIII, p. 463.

‡ Geognostische Beschreibung des Konigesiches Sachsen; 2 Heft. p. 122.

§ Dr. Hunt's Address, p. 46.

II.—THE HURONIAN SYSTEM.

In referring to the gneissic series of the Green Mountains, Dr. Hunt makes mention of my having, in 1862, "ventured to unite it with the Huronian system."* I am not aware of ever having done this, nor do I think that there are even good lithological reasons for assuming the identity of the two series. In the paper referred to by Dr. Hunt, in which I instituted a comparison betwixt the rocks of Norway and Canada, I endeavoured to point out the resemblance between the rocks of Tellemarken, or the Quartzose Group of the *Urschiefer* and Sir W. E. Logan's Huronian series as developed on the north shore of Lake Huron. As differing from these I expressly distinguished the Dovrefjeld slates, the Schistose Group of the *Urschiefer*, and pointed out their resemblance to the semi-crystalline schists of Vermont and Eastern Canada. The lithological differences betwixt the Tellemarken rocks and the Dovrefjeld slates, in Norway, are just as decided as between the Huronian series and the Green Mountain schists in North America. Enormous beds of quartzite and perhaps felsite, and peculiar conglomerates, characterise the Huronian, while micaceous, chloritic and argillaceous schists and serpentines distinguish the Green Mountain rocks. It may be that these differences are not sufficient to justify us in regarding them as belonging to different formations, but they would seem to afford grounds for distinguishing them as groups. Therefore in my paper on the subject,† I have separated the quartzose from the schistose division of the *Urschiefer*, the former and not the latter being identified with the Huronian. If it were considered advisable to distinguish the Green Mountain rocks as a separate formation, it would seem to me most advantageous for the science to use the term Cambrian for this purpose, as has already been done by eminent geologists, and as I propose to do on the present occasion.

It is unnecessary to introduce here a description of these Huronian rocks, or to advert to theoretical views regarding their origin. Some reference to these points will be found in the paper above referred to, and in my article "On the geological formations of Lake Superior." ‡

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* Dr. Hunt's Address, p. 33.

† Canadian Naturalist; VII, 161. ‡ Ibid; III N.S., p. 190.

III.—THE CAMBRIAN SYSTEM.

In studying the various geological formations which present themselves in Canada, it is impossible to avoid comparing their architecture, lithology and mineral contents with the same or similar formations in European countries. Any one who has had an opportunity of observing them will at once perceive that not only do the Dovrefjeld slates resemble our Eastern Townships rocks, but also that the primitive and transition rocks of Saxony have much in common with them. Moreover, in examining the manner in which the Eastern Townships rocks succeed each other, the analogous order of the schists of the Erzgebirge, at once presents itself to the mind, and suggests ideas as to the respective ages of the corresponding rocks in Canada.

When the traveller in the Saxon Erzgebirge mounts the steep escarpment which borders that range of mountains towards Bohemia, passes northward up the valley of Joachimsthal, and stands at last on the ridge overlooking to the south the valley of the Eger, with Carlsbad in the distance, he has entered the primitive region of Saxony, rendered classical in geology by the labours of Werner and his successors. If the journey is continued northward, by Annaberg, Elterlein, and Lössnitz to Stollberg, gneiss, mica schist, and clay slate formations are passed over successively, and at last unequivocal sedimentary and fossiliferous formations arrived at. The order of succession of these schists of Saxony afforded the foundation for the law long ago propounded by Werner that mica schist forms the lower, and clay slate or its substitutes, chlorite and talc schist, the upper part of the *Urschiefer*. Further, since the mica schist, in those districts where the primitive formations are present in all their completeness, is found to be supported by gneiss, it follows that in the architecture of these oldest rocks, the three groups of gneissic, micaceous and argillaceous schists succeed each other in ascending order. It must not, of course, be forgotten, that in some instances one or other of these groups may be absent; those which are present, however, always shew the order of succession here indicated.* This is observed not only in the Erzgebirge, but also in the Fichtelgebirge, the Südeten, the Riesengebirge, Scotland, Ireland, Norway and Hungary.

Turning now to south-eastern Quebec, and the States adjoining

* Naumann, Geognosie; II, 155.

it, we find that, following the line of the Grand Trunk Railway north-westward, the succession of primitive and even transition strata occurring in the Saxon Erzgebirge is repeated. After leaving the granite and gneiss of New Hampshire, we cross the mica schist district of Compton County, and then chlorite and clay slates from Sherbrooke to Richmond. From the latter place through the townships of Durham, Acton, and Upton, green and greyish slates, graphitic shales, granwacke sandstone and grey limestone in strata more or less highly inclined, are traversed. All this time the country becomes less and less hilly, the rocks less and less frequent, until near Britannia mills, or, still keeping in a north-west direction, near the village of St. Helene, the wide-spread alluvium of the St. Lawrence valley is reached, occupying an area of several thousand square miles, in which very few rock outcrops are observed. This area is said to be underlaid by the Utica and Hudson River formations, which again are said to overlie conformably the Trenton and Chazy limestones and the Calciferous and Potsdam sandstones. All these rocks form part of a series of sedimentary strata occupying certain areas in the valley of the St. Lawrence, lying horizontally or nearly so, and supposed to be of Lower Silurian age. The Potsdam sandstone is the lowest member of this group of strata, and is regarded as the oldest Silurian rock, and possessing even greater age than the mica schists and clay slates of the Eastern Townships. Indeed in the attempts which have been made at determining the age of the latter rocks, it has always been the rule to begin with the Potsdam sandstone as the oldest rock, and to assume that those to the eastward (regardless of their lithological characters) followed each other in ascending order. Any one who has studied the structure of similar regions in Europe, such as those above mentioned, can scarcely fail to come to the conclusion that the opposite of this assumption is the truth; that the oldest rocks are those of New England, and that as we come north-westward, we pass over more and more recent strata. This view would be maintained in spite of the prevailing dip to the south-eastward, which can only be accounted for by assuming, with Emmons, that the strata have been overturned, this, and indeed the plications of the whole series, having been caused by some enormous pressure from the south-east.

In distinguishing the Green Mountain series, Dr. Hunt seems to have been unable to leave the beaten track, in which he had previously travelled, and to regard the more eastern crystalline

rocks as the older instead of the newer. He still adheres to the idea that the Green Mountain rocks, because they apparently underlie the White Mountain mica schists, etc., are the older rocks. In referring to the Laurentian system, it has been shewn how entirely inconsistent with European experience this supposition is.

In the preceding section the opinion has been expressed that Dr. Hunt has gone too far in asserting the pre-Cambrian age of the Green Mountain schists. In maintaining their pre-Silurian age, however, he merely adopts a view advocated by myself as early as 1862. In describing the Dovrefjeld slates, and comparing them with similar rocks in the Quebec group and Green Mountain series, I made the following remarks: "Different views "prevail as to their age in different countries. In Cornwall they "are considered Devonian; in Scotland Lower Silurian; and in "Bohemia as in Norway, pre-Silurian. In Belgium, Rhenish "Prussia, Westphalia, and Nassau, they are by some geologists "regarded as Devonian, and by others as belonging to an older "formation. In East Russia, on the western slope of the Ural "Mountains, they are supposed to represent Lower Silurian strata. "A dissimilarity of views will probably continue to prevail as to "the position of these rocks, until the question is decided as to "what value, in the absence of fossils, the petrographical characters "of a group, taken in connection with its stratigraphical position, "should have in determining its age. Perhaps there prevails at "present too much of a tendency to attribute extraordinary influ- "ences to metamorphic agencies. So soon as the true limits and "effects of metamorphism are recognized, it will probably be ac- "knowledged that, whatever view may be entertained as to their "origin, the schistose rocks, above referred to, *underlie the Silu- "rian and all unaltered or metamorphosed fossiliferous strata.*"

In justifying the application of the term Cambrian to the rocks under consideration, I cannot do better than employ the language of Von Cotta, of which the following is a translation*—"It "cannot be doubted that the Lower Silurian strata are not the "very oldest sediments, which have been deposited from water, "but it is very difficult to separate distinct formations, lower "down, on account of the almost entire absence of organic re- "mains. Sedgwick believed that he had found such a formation

* Die Lebre von den Flöts formationen, p. 203.

"in the district which formerly constituted the ancient country "of the Cambrians in England, and he therefore called it the "Cambrian system. This formation was afterwards in greater "part united with the Silurian and so abandoned by English "geologists. Nevertheless it would appear advantageous to have "a general term for indicating those semi-crystaline and non-fos- "siliferous strata, which frequently underlie Silurian beds still "containing organic remains, and interpose themselves in large "quantity between those and the distinctly crystalline schists. "For this purpose I apply the term Cambrian Formation, be- "cause it has been introduced and is to a certain extent used in "this sense. I regard such a title as better than 'non-fossilifer- "ous Clay slate' because it indicates a certain horizon, and does "not refer to a rock which occurs earlier and later, and is not the "exclusive product of this period. The Cambrian Formation "consists principally of clay slate, which passes into grey wacke "slate and also into mica schist, with subordinate intercalations "of quartz slate, kieselschiefer, alumshale, limestone, ironstone, "and sometimes also sandstone and conglomerate. But since "extensive districts of Silurian and Devonian strata, of similar "lithological character, sometimes contain no fossils at all, they "may sometimes be easily mistaken for the Cambrian. On this "account the name must be applied with great care, and only in "cases where such non-fossiliferous, semi-crystalline beds are "overlaid by Silurian rocks. This is the case with Barrande's "Azoic Formation in Bohemia; with the Clay slate district "between Oederan, Lössnitz, Reichenbach and Oelsnitz;" the Saxon district above referred to, "in the neighbourhood of "Greitz; in the Fichtlelgebirge at Rehau and Gefäll. In all "likelihood the Clay slate district on the south declivity of the "Riesengebirge, the clay slates in the eastern Südeten, the clay "slates of the Taunus and the Hundsrück, the roofing slates of "the Ardennes and perhaps a portion of the killas of Cornwall, "belong to the Cambrian system."

IV.—THE SILURIAN SYSTEM.

We have already seen that, in comparing the great mass of the New England and Eastern Township rocks with strata of similar lithological characters in Europe, such as those of Saxony above alluded to, there is no difficulty in recognising them as Azoic and

pre-Silurian. This applies to the gneiss, mica schist, chlorite schist, and to much of the clay slate of the region referred to. As in Saxony there exists a passage (perhaps only apparent) from these crystalline and semi-crystalline rocks into others of a distinctly detrital and fossiliferous character, so, in the Eastern Townships, we have a similar passage from roofing slate into softer grey slates, grauwacke (Sillery sandstone), graptolitic shales and fossiliferous limestones. This peculiar structure was indeed the reason why these oldest fossiliferous strata were formerly called the Transition (*Uebergang*,) Formation. The same series of rocks, in the Province of Quebec, occupies a belt along the west side of the Quebec group having a breadth of about twenty miles and including all undoubtedly sedimentary and fossiliferous strata. It is this same band of rocks which continuing southwestward into Vermont, has there been called the Taconic, and which Dr. Hunt wishes to classify as Upper Cambrian. We have already seen that the term Cambrian is much more applicable to the Green Mountain series, and there would appear to be no good reason for ceasing to regard these rocks as belonging to the Silurian system. As has already been explained, however, it would be proper to exclude from that series any non-fossiliferous rocks whose aspect is semi-crystalline, and which have been so frequently classed as metamorphic Lower Silurian. These, as we have seen, it is much more reasonable to class with the Cambrian rocks.

In several parts of Dr. Hunt's Address reference is made to the fact that the fossiliferous rocks here referred to, Quebec group, Taconic, Transition or whatever they may be called, are unconformably overlaid by the more horizontal rocks of the Champlain division. He makes no attempt to show that the evidence of this unconformability is fallacious, and, nevertheless proceeds to combine both groups into one formation—and that the Cambrian. Emmons alone, of all the geologists who have examined these rocks, appears to have ascribed to this matter of unconformability the importance which it deserves. "When "two stratified rocks follow each other in discordant succession "then their formation must have been separated by a great space "of time, during which the lower or older rock must have ex- "perienced a violent disturbance of its original position."* It is scarcely allowable in Geology to regard two such rocks as part

* Naumann, Geognosie; II, 15.

of the same formation, or even system. "A geological formation "is made up of very widely distributed or very numerous rock "members, which form an independant whole, and are by their "lithological and palæontological characters as well as by their "structure and stratigraphical position recognizable as contem- "poraneous products of similar natural processes." † The terms system, series, and formation have been used for expressing this idea, but the name employed is immaterial; two rocks or groups of rocks, unconformable to each other, must belong to different systems. If, therefore, the mutual relations of the so-called Taconic and Champlain rocks have been accurately described by Emmons and others and if, as we have supposed, these so-called Taconic rocks are of Silurian age, it follows that the Champlain division cannot be Silurian but must belong to a newer series, such as the Devonian, Carboniferous, Permian or Triassic.

V.—THE CARBONIFEROUS SYSTEM.

The only representative of this series heretofore supposed to exist in the Province of Quebec, is the Bonaventure formation. Nowhere else has the existence of carboniferous strata been suspected or regarded as likely. Such existence has not been denied, but no hope has ever been held out of the possibility of discovering productive coal measures within the limits of the Province. It cannot, however, be maintained that throughout its whole extent it has undergone such a thorough examination as to enable our geological authorities to assert its absolute destitution as regards paying beds of coal. There are immense areas in the valley of the St. Lawrence, occupied by lake and swamp, sand and clay, where no rocks come to the surface, and where no enteprising oil seeker has ever pierced the underlying strata. The rocks around the margin of these areas have indeed been examined, and the result has not been favourable to the idea that coal may exist beneath them. If, however, as I believe, erroneous ideas prevail as to the true order of succession among these rocks; if the newer rocks of the Eastern Townships succeed the older towards the north-west, and not in the opposite direction, it becomes a matter of much importance to ascertain, with certainty, what geological formations exist beneath the alluvium of the St. Lawrence valley.

Reference has already been made to the order of succession

† Naumann, Geognosie; II, 3.

among the schistose rocks of the Erzgebirge. It was shewn that in passing from Bohemia through Saxony, to the north-westward, gneiss, mica schist, and clay slate districts are successively traversed. After leaving the clay slate near Stollberg, we reach in a very short time the *Rothliegende* of the Chemnitz valley, or the new red sandstone. We thus pass from Silurian to Permian strata in a few steps, and were we not better informed, would not imagine that the vast interval of the Carboniferous period interposed betwixt them. If, instead of taking the route from Annaberg to Chemnitz, the traveller had kept more to the westward, through Schneeberg and Wiesenburg to Zwickau, he would, after leaving the clay slates, have passed over the upturned edges of graphitic schales, kieselschiefer and grauwacke sandstones and slates, and at last have encountered the steam and bustle and waste heaps of busy collieries, telling of the wealth of mineral fuel beneath. But neither in the neighbourhood of Zwickau would he find any outcroppings of Carboniferous strata. These are overlapped and concealed by the *Rothliegende*, which extends over their edges to the Grauwacke.

We have already seen that entirely similar rocks to those which so closely border on the Carboniferous in Saxony, exist in our Eastern Townships, and especially in Durham, Acton and Upton, and we have maintained that among these rocks the more recent are to be found to the north west, and not to the south-east. If this is the case, there are reasons for suspecting that carboniferous rocks may succeed them on the north-west, and may be hid beneath sand, clay, and newer horizontal strata. In Saxony, as we have seen, similar transition rocks are succeeded by carboniferous strata, and this is also the case in Rhenish Prussia, Belgium, Pennsylvania, and elsewhere. We may suppose, indeed, that Devonian strata may intervene to the westward, but even in this case, there might still be some space left before reaching the Laurentian, in which coal measures might be secreted. The very fact that there exists in the valley of the St. Lawrence an area of several thousand square miles in which few rock outcrops are observable, and whose geology is consequently more or less problematical, ought alone to render us cautious in accepting the conclusion that carboniferous strata cannot possibly exist beneath it. There are, moreover, numerous points in this area at which springs occur, yielding carburetted hydrogen. These have been mentioned in the "Geology of Canada," from which it appears

that the mineral springs of Assumpsion, Baie du Febvre, Caledonia, Chambly, Lanoraie, St. Leon and Varennes, yield large quantities of carburetted hydrogen, which is supposed to be evolved from the underlying Lower Silurian rocks. But the production of this gas in such quantity only takes place in the process whereby large accumulations of vegetable matter are converted into coal. The circumstances under which it is disengaged would exclude the hypothesis that it arises from the decomposition of vegetable matter in marshes, or alluvium, which at any rate only yield it in inconsiderable quantity.

To all this it will, of course, be replied that the valley of the St. Lawrence is occupied by Lower Silurian rocks, and that carboniferous strata cannot exist beneath them. I have, however, attempted to shew that since these so-called Silurian or Champlain rocks rest unconformably upon the Transition or Grauwacke or Taconic series, they must be of later age. Further, the notion of the extreme antiquity of the Potsdam sandstone and its associates, seems to me untenable, for the following reasons: 1st. It lies almost horizontally, and comparatively undisturbed, while the strata supposed to be more recent have undergone the most violent upheavals, and occupy a highly inclined and frequently vertical position. One of the most unequivocal results which the study of American geology has yielded is this, that the paroxysm which raised and plicated the whole of the Appalachian chain, took place at a time subsequent to the Carboniferous age. The coal measures of Pennsylvania are found to have been corrugated by the same movements which affected our Eastern Township rocks, and it seems impossible that these movements could have left the Potsdam sandstone undisturbed, had it, at that time, occupied the position it now has in the St. Lawrence valley. 2nd. At several points along the eastern shore of Lake Champlain, strata identical with the Potsdam sandstone, or conformable with it, are found to cover unconformably highly inclined strata, belonging to the same system as the Quebec group. 3rd. In palæontological respects the true Potsdam sandstone, as developed in the valley of the St. Lawrence, does not show evidence of very great antiquity. It is destitute of graptolites and trilobites which are usually supposed to be characteristic of Lower Silurian strata. 4th. The Potsdam Sandstone is described as containing near Hemmingford Mountain fragments of black shale, which goes to prove the existence of the latter before the deposition of the

sandstone. The true age of the Potsdam sandstone I believe to be Permian or Triassic, partly on account of the reason first above given, and partly on account of the geological relations of similar sandstones in north-western Ontario which have yet to be referred to. Its position entirely corresponds to the *Rothliegende* of the Chemnitz Valley already mentioned, and like the latter rock, it may overlie and conceal Carboniferous strata.

The structure of the Transition and Carboniferous systems of the Rhein lands, and of the superimposed Permian or Triassic strata, is exceedingly interesting in connection with this question, on account of the gradual and conformable succession which is observable from the characteristic clay slates of the Ardennes, Hundsrück, Taunus and Westerwald to the coal basins of Belgium, Rhenish Prussia, Westphalia and Nassau.* In the whole of this Rhenish Transition district the prevailing strike of the strata is from E. N. E. to W. S. W. and the dip changes from northward to southward with the greatest irregularity, a continual repetition of anticlinal and synclinal belts of strata being observable. The upheaval of the originally horizontal system of strata was consequently accompanied by numerous parallel foldings and must have been caused by an enormous and wide-spread force working in a direction from S. S. E. to N. N. W. The epoch of this elevation falls beeween the Carboniferous and Permian periods, for the North Rhenish coal basin has been affected by it in a similar way, while the magnesian limestone of Stadtberg lies in undisturbed horizontal strata on the abraded edges of the highly inclined transition slate.

It is unnecessary here again to point out the resemblance which this example of a transition formation bears to the Lower Silurian of our Eastern Townships rocks. Nor is it necessary further to elaborate the theory I have advanced which reverses entirely their supposed order of succession. It may be that in bringing forward these views I have done a foolhardy and presumptuous thing. But I entertain the conviction that the truth will sooner or later prevail, and am not without hope that my theory will one day be recognized as consistent and well-founded.

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* Nauman, Geognosie I, 379.

VI.—PERMIAN AND TRIASSIC ROCKS.

In the summer of 1865 I had abundant opportunity for examining the cupriferous rocks of Maimause and Michipicoten Island, on the Canadian shore, as well as those of Point Keweenaw on the south shore of Lake Superior, which I afterwards described.* Assuming that in the absence of palæontological evidence, lithological characters should not be entirely neglected, I pointed out the resemblance between these rocks and the German Rothliegende, and remarked: "It becomes a matter of much importance "and deserving of the most careful study, to ascertain whether "this resemblance is a mere coincidence, or whether there is any "reason for supposing that any part of these Upper copper-bearing "rocks are of Permian age." In the same paper I called attention to the fact that the Maimause group is, at Point aux Mines, overlaid unconformably by conglomerate and thin bedded bluish-grey sandstones, but owing to lithological differences, I hesitated to regard them as conformable with the red sandstone of the neighbourhood of Batchewahnung Bay.

The greater part of the season of navigation in 1868, '69, and '70, was spent by me among the rocks of the north-western shores of Lake Superior, where I speedily observed that the argillaceous sandstones of the "lower group" of the Upper copper-bearing rocks much resembled the bluish-grey flagstones of Point aux Mines above referred to. I further mapped out the ground on Woods Location, in the neighbourhood of Thunder Cape, where these grey argillaceous sandstones are conformably overlaid by the red and grey sandstones of the "upper group."† This survey of Woods Location seemed to me to furnish grounds for regarding the flags of Point aux Mines as being conformable with the sandstones of Batchewahnung and Sault Ste. Marie, and the latter as being consequently unconformable with and newer than the Maimause and Michipicoten groups. This is fully confirmatory of Sir W. E. Logan's suspicion of a "want of conformity between "the Sault Ste. Marie sandstones and the trappean rocks beneath.‡ Sir William's observation of the unconformable superposition of red sandstone layers on the traps of Isle Royale,§ would indicate

* Geology of Canada, 1866, 132; Canadian Naturalist; III, N.S. 1, 241.

† Canadian Naturalist; IV, N.S., pp. 37 and 459.

‡ Geology of Canada, p. 85. § Ibid, p. 79.

that the latter belong to the same series as the Maimause, Michipicoten and Keweenaw copper-bearing groups. My explorations also enabled me to ascertain the true position of the trap of Thunder Cape, one of the most conspicuous headlands on Lake Superior. Even from the deck of the steamer on passing it, this promontory may be observed to consist of almost horizontal grey flags and shales, surmounted by a covering of columnar rock. On closer examination, the latter rock is found to overlie unconformably not only the grey flags but also the conglomerate and sandstones which succeed them to the east. Instead therefore of being a member of the Upper copper-bearing series, the trap or hyperite of Thunder Cape is newer than any part of that group, and has formed an overflow of immense area extending south-westward to and beyond Pigeon River.

From my observations on Lake Superior I would argue the existence of three separate formations there, besides the Laurentian and Huronian series. These formations mentioned in the order of their antiquity are as follows:

I. Conglomerates, breccias, sandstones, melaphyres, porphyrites, amygdaloids and aphanites of Michipicoten, Maimanse, Isle Royale and Point Keweenaw.

II. Conglomerates, gray red and white sandstones, indurated marls, angitic porphyries, melaphyres, trachytes and basalts of Kaministiquia river, Point Porphyry, Isle St. Ignace, &c.

III. Hyperite overflow of Thunder Cape and of the region south-west from Fort William.

In thus distinguishing three different ages among the Upper Copper bearing rocks of Lake Superior, I have, of course, been much influenced by the fact of their unconformability, just as in the case of the Quebec group and Champlain rocks. It thus follows that these Lake Superior rocks cannot be wholly of Permian age even if part of them should be judged to belong to that formation. For the reasons given in the paper above cited,* I am still inclined to regard Group I of these rocks as identical with certain Permian strata in Europe; Group II would seem to belong to the Triassic system, as it overlies unconformably Group I, and exhibits many of the petrological characters possessed by the variegated sandstone (*Bunt sandstein*) or upper new red sandstone of Europe. These resemblances are to be observed among

* Canadian Naturalist, III, p. 256.

the argillaceous sandstones of the Kaministiquia district, and of Point aux Mines, as well as among the red and white sandstones of Thunder Cape, Batchewahnung and Sault Ste. Marie. The variegated colours exhibited by the *Bunt sandstein* in Europe, and especially in Thüringia, and which have given rise to its name, may be observed about eight miles to the east of the extremity of Thunder Cape. Here the sandstones shew red, white, and greenish colours, mixed with each other in stripes and spots, or succeeding each other in thin layers. Occasionally the yellowish white or lightred sandstones have spots or patches of dark brown, so coloured by peroxide of iron. The argillaceous sandstones of the Kaministiquia district, with their frequent heavy-spar veins, have a good many points of resemblance with certain parts of the *Bunt sandstein* in Rhenish Prussia, Wirtemberg, and Thüringia. Besides these general features which these European and Canadian rocks have in common, the following particular coincidences may be mentioned: 1st. The concretions described as occurring in the sandstones of Point aux Mines resemble exactly the *Thongallen* which have long been regarded as thoroughly characteristic of the *Bunt sandstein* in Central Germany. 2nd. The grey sandstones of Thunder Cape are frequently cut by vertical joints of great regularity, and also separated into thin flags, by intervening layers of shaly sandstone. These flags are often so thin that there would appear to be no difficulty in using them as roofing slate. In this particular they resemble certain beds of the Bunt sandstein at Reraux, near Plombieres, at Nussloch and Weibstadt in Baden, and at Solling, which yield good material for roofing and paving. 3rd. The sandstones and marls developed on the west side of the entrance to Black Bay, possess a matrix consisting sometimes of pure dolomite.* This is a peculiarity which, according to Zirkel, has hitherto been remarked only among *Bunt sandstein* rocks.

That fossils have not yet been detected in these supposed Triassic rocks of Lake Superior need not create much surprise, when it is considered that the *Bunt sandstein* in Europe is generally very poor in organic remains. Indeed it is usually throughout its whole thickness destitute of any fossiliferous strata, and it is only a few districts that make exceptions to this rule, and exhibit some fossils identical with those of the *Muschel Kalk*. It

* Canadian Naturalist; IV, 39.

is also to be remarked that no very thorough search has as yet been made for fossils in the Lake Superior region, and that, as in Europe, such argillaceous sandstones as those west of Thunder Cape, may yet yield the organic remains necessary for the thorough identification of the formation.

According to those views the Lake Superior sandstones would be of the same age as the Upper new red sandstones of Nova Scotia and Prince Edward Island, which is coloured as Triassic on the Geological map of Canada. Dr. Dawson's descriptions of this formation in Nova Scotia shew many points of resemblance between it and the Lake Superior rocks. Amygdaloid and trap are found to overlie both sandstone formations, and the rocks of Blomidon correspond to those huge beds of a similar nature which cover the sandstone and form the broken coast and archipelago extending from Point Porphyry to Battle Islands. Large concretionary balls are mentioned as occurring in the sandstone at Shubenacadie, which may likely enough have the characters of *Thongallen*, and native copper which occurs in tolerable quantity in the Triassic traps of Lake Superior, also occurs in veins intersecting the trap of Cape d'Or.

It is of course to be anticipated that very serious objections will be raised against the views just expressed. It will probably be maintained that the St. Mary sandstone is conformably overlaid by strata whose fossils prove them to be of Silurian age. These strata occupy a region east of Sault Ste. Marie, with which I am not intimately acquainted, but nevertheless I would consider that the facts and analogies above mentioned would justify a re-examination of the district in question.

Acton Vale, P.Q., September, 1871.